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# WARTIME REPORT

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WIND-TUNNEL INVESTIGATION OF A SECTION OF THE  
HORIZONTAL TAIL SURFACE FOR THE BELL XP-63 AIRPLANE

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MEMORANDUM REPORT

for the

Materiel Division, U. S. Army Air Corps  
WIND-TUNNEL INVESTIGATION OF A SECTION OF THE  
HORIZONTAL TAIL SURFACE FOR THE BELL XP-63 AIRPLANE

By Milton B. Ames, Jr., and H. Page Hoggard, Jr.

INTRODUCTION

At the request of the Materiel Division, U. S. Army Air Corps, force tests have been conducted on a model of a section of the XP-63 horizontal tail surface in the 4- by 6-foot closed-throat vertical wind tunnel of the National Advisory Committee for Aeronautics. The tests were made to determine the aerodynamic section characteristics of a modified low-drag airfoil with a  $0.26c$  flap having a  $0.305c_f$  overhang and a  $0.40c_f$  tab. The model was tested with several elevator nose shapes and with a gap of  $0.001c$  at the elevator nose and also with the gap sealed. Because a conventional control surface or elevator is comparable to a flap on an airfoil, these terms are used synonymously in this report.

### MODEL AND APPARATUS

The 2-foot chord by 4-foot span model was made of mahogany and was furnished by the Bell Aircraft Corporation. The model had an airfoil section which conformed to the NACA 66,2x-009 profile ahead of the 75-percent chord station, but had a modified trailing edge rear of this station. The ordinates for the modified section are given in table I. The flap had a chord of 0.26 of the airfoil chord measured from the flap hinge axis to the airfoil trailing-edge. The flap overhang ahead of the hinge axis was 0.305 of the flap chord and the tab chord was 0.40 of the flap chord. Two flap-nose shapes were originally constructed for the tests, and these nose shapes are shown in figure 1. The blunt nose on this drawing will hereafter be referred to as the Bell blunt nose and the radial nose as the NACA blunt nose. After the preliminary tests of the NACA and Bell blunt-nose shapes had been completed, a third nose shape, the NACA medium nose, (see fig. 1) was designed and tested.

The tests were made in the NACA 4- by 6-foot vertical wind tunnel which has a closed test chamber and return passage. The regular three-component balance was used to measure the lift, drag, and

pitching moments. The flap hinge moments were measured by a special hinge-moment balance. Because the model completely spanned the test chamber, except for small clearances at each end, two-dimensional flow was approximated.

### TESTS

The dynamic pressure was maintained constant throughout the tests at 15 pounds per square foot corresponding to an airspeed of about 76 miles per hour at standard sea-level conditions. The test Reynolds number was approximately 1,430,000 and the effective Reynolds number of the tests was approximately 2,760,000, based on a turbulence factor of 1.93 for the 4- by 6-foot vertical tunnel.

The angle-of-attack range was from the negative to the positive stall for all flap deflections. The flap was tested over a range of deflections from  $0^{\circ}$  to  $30^{\circ}$  in  $5^{\circ}$  increments with each of the flap-nose shapes and with the 0.001c gap at the flap nose. Tests were also made with the NACA blunt-nose flap with the gap sealed with grease. The tab tests were made with the NACA blunt-nose flap and with the tab and flap gaps sealed with grease at tab deflections of  $0^{\circ}$ ,  $\pm 10^{\circ}$ , and  $\pm 15^{\circ}$  for flap deflections of  $0^{\circ}$ ,  $10^{\circ}$ ,  $15^{\circ}$  and  $20^{\circ}$ .

After the completion of the regular test program, the irregularities on the surfaces of the model caused by the flap and tab nose cut-outs were completely faired with modeling clay and a test was made with the flap and tab neutral to determine the minimum drag of the model.

### RESULTS

The results are given in the form of section coefficients of lift, drag, pitching moments, and flap hinge moments.

$$c_l = \frac{l}{qc}$$

$$c_{d_o} = \frac{d_o}{qc}$$

$$c_m = \frac{m}{qc^2}$$

$$c_{h_f} = \frac{h_f}{qc_f^2}$$

where

$c_l$  airfoil section lift coefficient

$c_{d_o}$  airfoil section profile-drag coefficient

$c_m$  airfoil section pitching-moment coefficient  
about quarter-chord point of airfoil

$c_{h_f}$  flap section hinge-moment coefficient

and

$l$  airfoil section lift

- $d_o$  airfoil section profile drag
- $m$  airfoil section pitching moment about  
quarter-chord point of airfoil
- $h_f$  flap section hinge moment
- $q$  dynamic pressure lb/sq ft
- $c$  chord of airfoil with flap and tab neutral
- $c_f$  chord of flap with tab neutral
- $\alpha_o$  angle of attack for airfoil of infinite  
aspect ratio
- $\delta_f$  flap deflection with respect to airfoil
- $\delta_t$  tab deflection with respect to flap

Only the values of the lift coefficients have been corrected for tunnel effects. The tunnel correction for drag is large but no satisfactory method of applying a correction for drag has been found. In any case the drag results of the low-drag type of wing in a turbulent air stream are not believed to be reliable.

The aerodynamic section characteristics of the airfoil with the Bell blunt- and the NACA blunt- and medium-flap-nose shapes and with the 0.001c gap at the flap nose are presented in figures 2, 3, and 4, respectively. The aerodynamic section characteristics are presented for the sealed-gap condition of the NACA blunt-nose flap in figure 5.

The profile drag coefficients for the faired model, and the model with the various flap-nose-shape and gap variations, are plotted for flap and tab neutral in figure 6. With the faired-model condition as a basis, the drag-coefficient increments caused by flap deflections are plotted in figure 7 for angles of attack of  $\pm 8^\circ$ ,  $\pm 4^\circ$  and  $0^\circ$ . While the absolute values of the profile-drag coefficients are uncorrected, it is believed that the values of the increments are free from tunnel effects.

The results of the tab tests of the airfoil with the NACA blunt-nose flap and with tab and flap gaps sealed are presented in figures 8, 9, 10, and 11 for flap deflections of  $0^\circ$ ,  $10^\circ$ ,  $15^\circ$ , and  $20^\circ$ , respectively, with tab deflection of  $0^\circ$ ,  $\pm 10^\circ$ , and  $\pm 15^\circ$  for each flap deflection.

#### DISCUSSION

In order that the test program might be kept at a minimum to expedite the forwarding of the data, a very brief analysis of the results was made at the completion of the flap-nose-shape tests for the 0.001c gap condition. The purpose of this analysis was to determine which flap-nose shape should be used for the sealed gap and the tab tests. The values of  $c_d$  as affected by flap-nose shape are

plotted against  $\delta_f$  in figure 12 for angles of attack of  $-8^\circ$ ,  $0^\circ$ , and  $8^\circ$ . The hinge-moment characteristics of the Bell blunt-nose flap, the NACA blunt-nose flap, and the NACA medium-nose flap, respectively, are plotted against  $\alpha_o$  and  $\delta_f$  for the 0.001c gap condition. (See figs. 13 to 15.) The nose shapes were also compared in figure 16, where the increments of  $c_l$  and the increments of  $c_{h_f}$  caused by flap deflection are plotted for a high negative angle of attack,  $0^\circ$  angle of attack, and a high positive angle of attack. On the basis of this analysis it was concluded that the NACA blunt-nose flap was the most satisfactory from a consideration of both the lift effectiveness and the balance effectiveness of the flap. Accordingly, the sealed-gap tests and the tab tests were made using only the NACA blunt-nose flap. Plots of  $c_l$  versus  $\delta_f$ ,  $c_{h_f}$  versus  $\alpha_o$ ,  $c_{h_f}$  versus  $\delta_f$  for the NACA blunt-nose flap with the gap sealed are presented in figures 17 and 18.

In addition to the drag data presented in figures 6 and 7, the following table of uncorrected minimum profile-drag coefficients is presented.

Model condition	$c_{d_{min}}$ (uncorrected)
Model faired	0.0082
Model { with Bell blunt-nose flap, 0.001c gap	0.0088
Model { with NACA blunt-nose flap, 0.001c gap	0.0092
Model { with NACA blunt-nose flap, gap sealed	0.0092
Model { with NACA medium-nose flap, 0.001c gap	0.0091

By the use of aerodynamic parameters (reference 1) and the data from tests of a conventional airfoil with a 0.30c flap (reference 2) the characteristics of an NACA 0009 airfoil with a 0.26c flap having a  $0.305c_f$  overhang have been estimated. In the following table a brief comparison of the control-surface characteristics of the modified low-drag airfoil and the conventional airfoil has been made for the condition of infinite aspect ratio.

	Test Results	Estimated Results (refs. 1 & 2)
Parameter	Modified NACA 66,2x-009 Airfoil, 0.26c NACA blunt-nose flap, 0.305c <sub>f</sub> overhang, sealed gap.	NACA 0009 Airfoil, 0.26c NACA blunt-nose flap, 0.305c <sub>f</sub> overhang, sealed gap.
$\left(\frac{\partial c_l}{\partial \alpha_o}\right)_\delta$	0.094	0.097
$\left(\frac{\partial c_l}{\partial \delta_f}\right)_{\alpha_o}$	.052	.053
$\left(\frac{\partial \alpha_o}{\partial \delta_f}\right)_{c_l}$	-.55	-.55
$\left(\frac{\partial c_{h_f}}{\partial \alpha_o}\right)_\delta$	-.0020	-.0037
$\left(\frac{\partial c_{h_f}}{\partial \delta_f}\right)_{\alpha_o}$	-.0050	-.0053
$\left(\frac{\partial \delta_f}{\partial \alpha_o}\right)_{c_{h_f}=0}$	-.40	-.70
$\left(\frac{\partial c_m}{\partial c_l}\right)_\delta$	.0010	.0010
$\left(\frac{\partial c_m}{\partial \delta_f}\right)_{c_l}$	-.0095	-.0095
$c_{l_{max}} \begin{cases} \alpha_o \\ -8^\circ \\ 0^\circ \\ 8^\circ \end{cases}$	0.22 at $\delta_f = 20^\circ$ 0.79 at $\delta_f = 15^\circ$ 1.26 at $\delta_f = 25^\circ$	0.28 at $\delta_f = 20^\circ$ 0.85 at $\delta_f = 16^\circ$ 1.36 at $\delta_f = 11^\circ$
$c_{d_{o_{min}}}$	0.0092 (uncorrected)	0.0098 (uncorrected)

Langley Memorial Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., August 29, 1941.

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1. Ames, Milton B., Jr., and Sears, Richard I.:  
Determination of Control-Surface Characteristics from NACA Plain-Flap and Tab Data.  
NACA TN No. 796, 1941.
2. Ames, Milton B., Jr.: Preliminary Data of a  
Wind-Tunnel Investigation of an NACA 0009  
Airfoil with a 0.30c Flap Having a  
Systematic Variation of Flap Nose Shape  
and Aerodynamic Overhang. NACA ARR,  
Aug. 1941.

TABLE-I. Ordinates for Modified NACA 66<sub>21</sub>-009<sub>1</sub> Airfoil  
(Stations and Radials in percent of wing chord)

Stations	Upper Surface	Lower Surface
0	0	0
.5	.65	-.65
.75	.78	-.78
1.25	.96	-.96
2.50	1.29	-1.29
5	1.78	-1.78
7.5	2.17	-2.17
10	2.50	-2.50
15	3.05	-3.05
20	3.48	-3.48
25	3.83	-3.83
30	4.10	-4.10
35	4.29	-4.29
40	4.43	-4.43
45	4.49	-4.49
50	4.48	-4.48
55	4.40	-4.40
60	4.20	-4.20
65	3.86	-3.86
70	3.35	-3.35
75	2.79	-2.79
80	2.18	-2.18
96.06	.60	-.60
L.E. Radius:	.55	T.E. Radius: .10

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Note: See Bell Aircraft Corp. drawing No. 24-943-005 for reference.

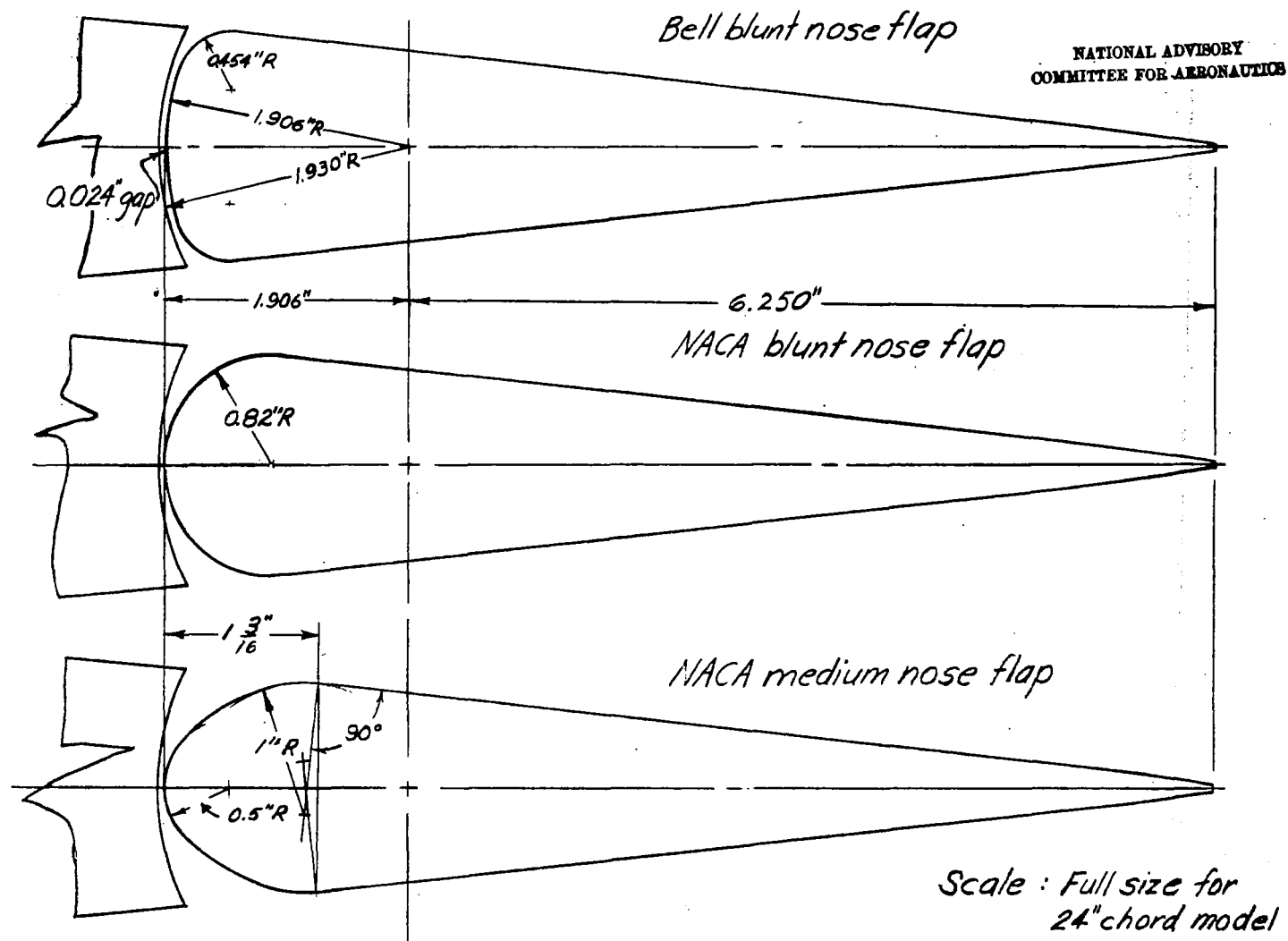


Figure-1. Flap nose shapes tested on XP-63 horizontal tail section 24" chord model.

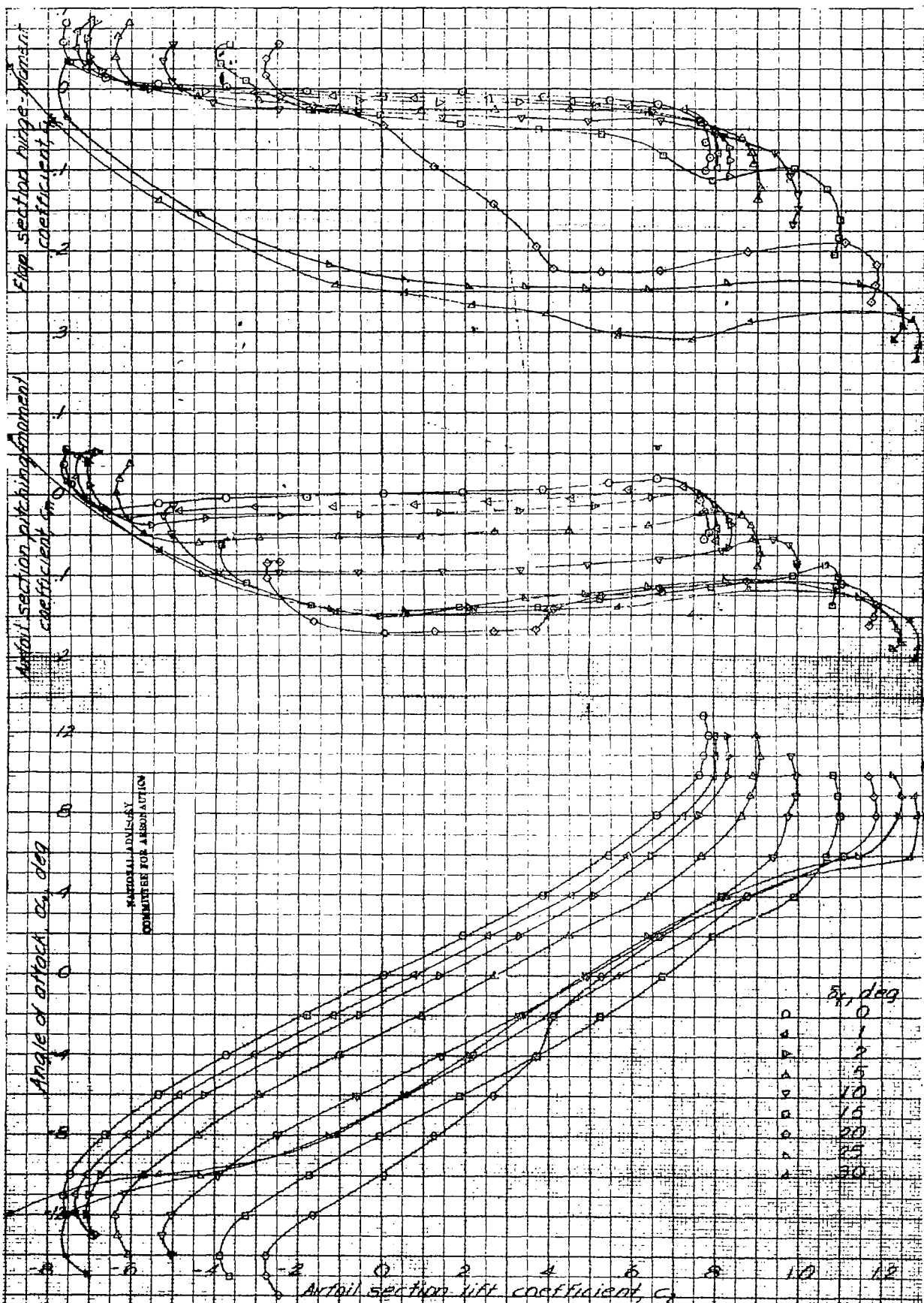


Figure 2. Section characteristics of an airfoil for XA63 horizontal tail Bell blunt nose flap gap = 0.004c,  $\delta_f = 0^\circ$

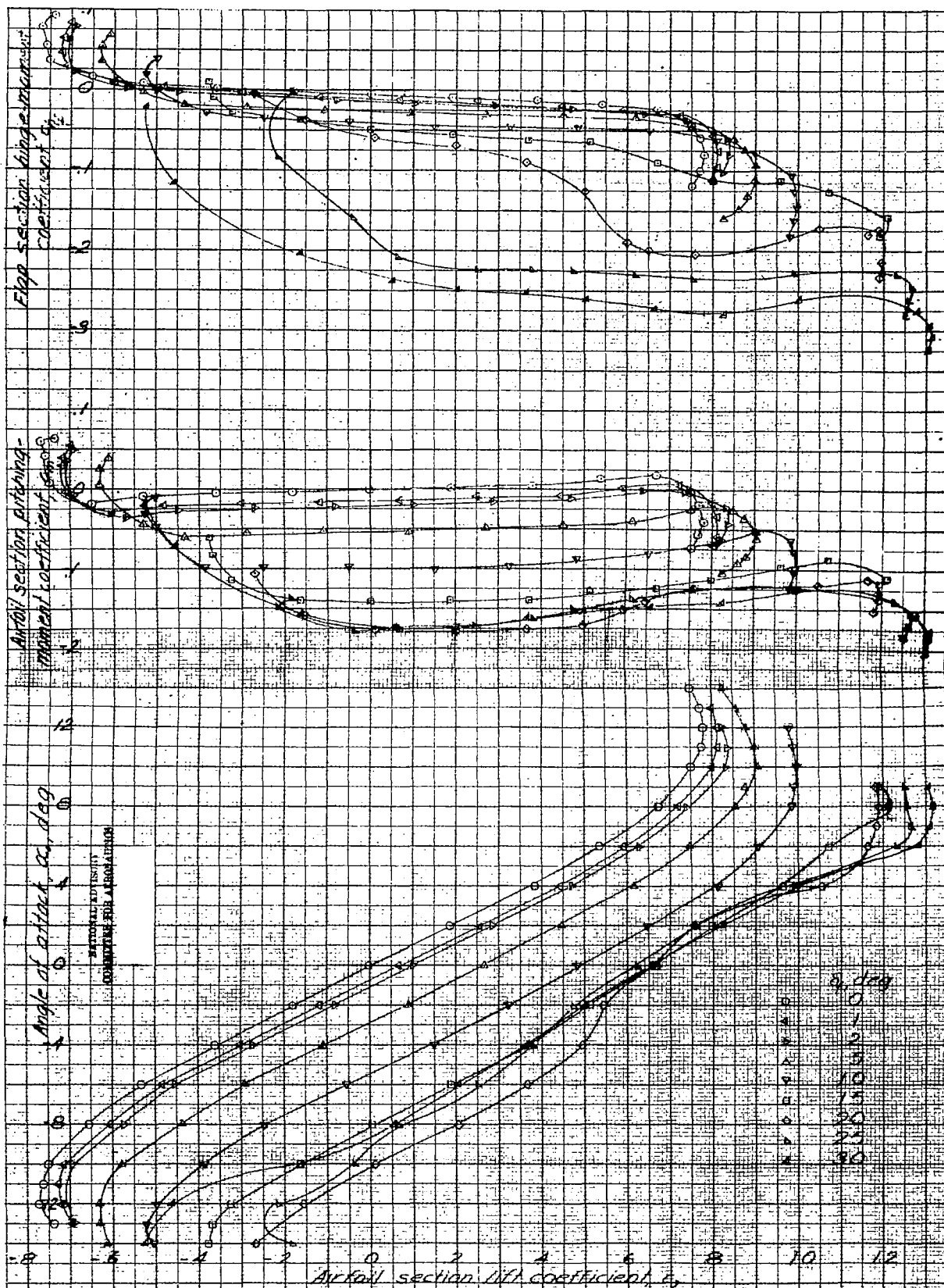


Figure - 3. Section characteristics of an airfoil for KP63 horizontal tail. NACA 0012 nose flap. Gap = 0.0012,  $\delta = 0^\circ$

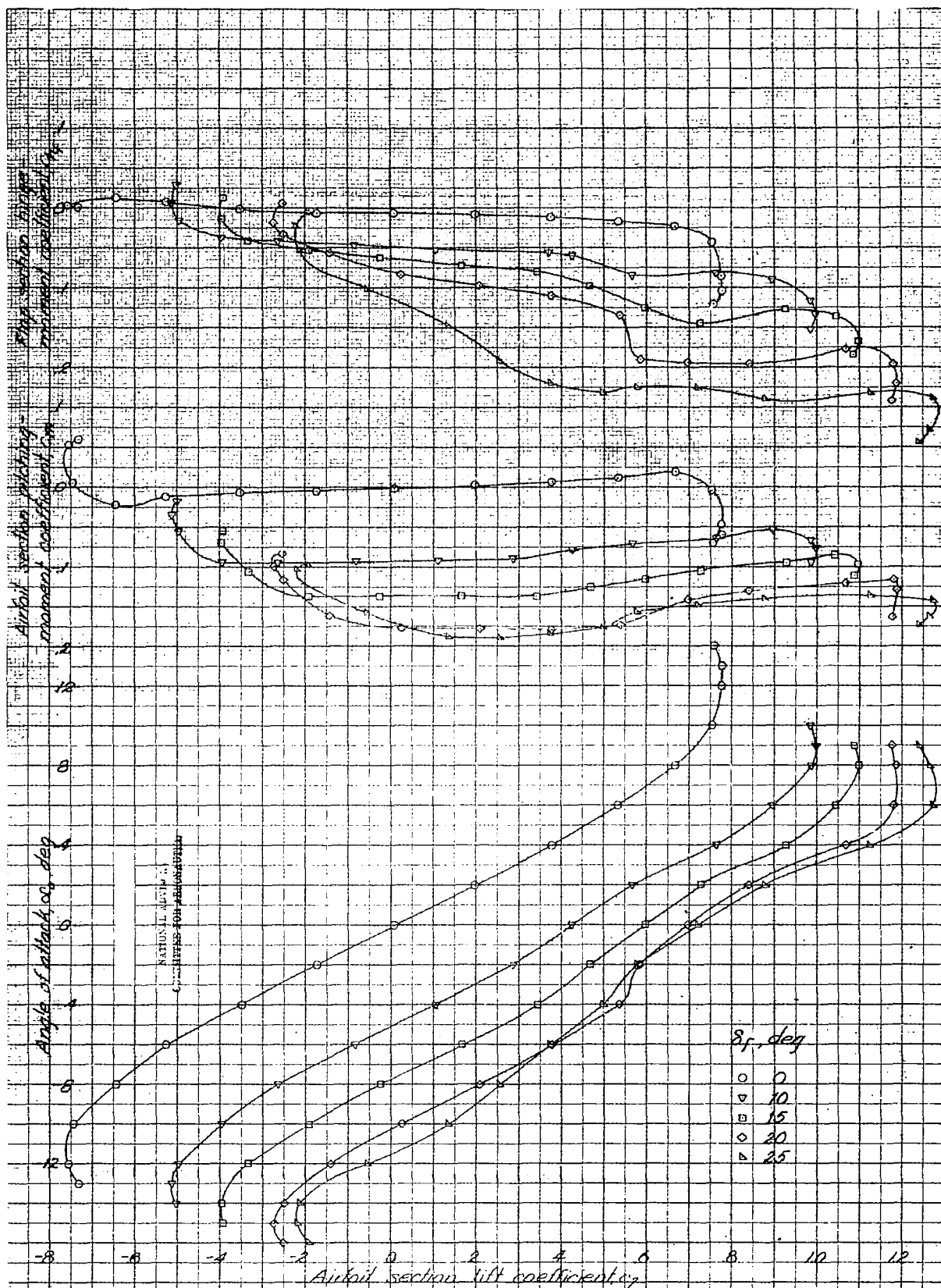


Figure - 4. Section characteristics of an airfoil for XP-63 horizontal tail NACA medium nose flap. Gap 0.001c,  $\delta_f = 0^\circ$ .

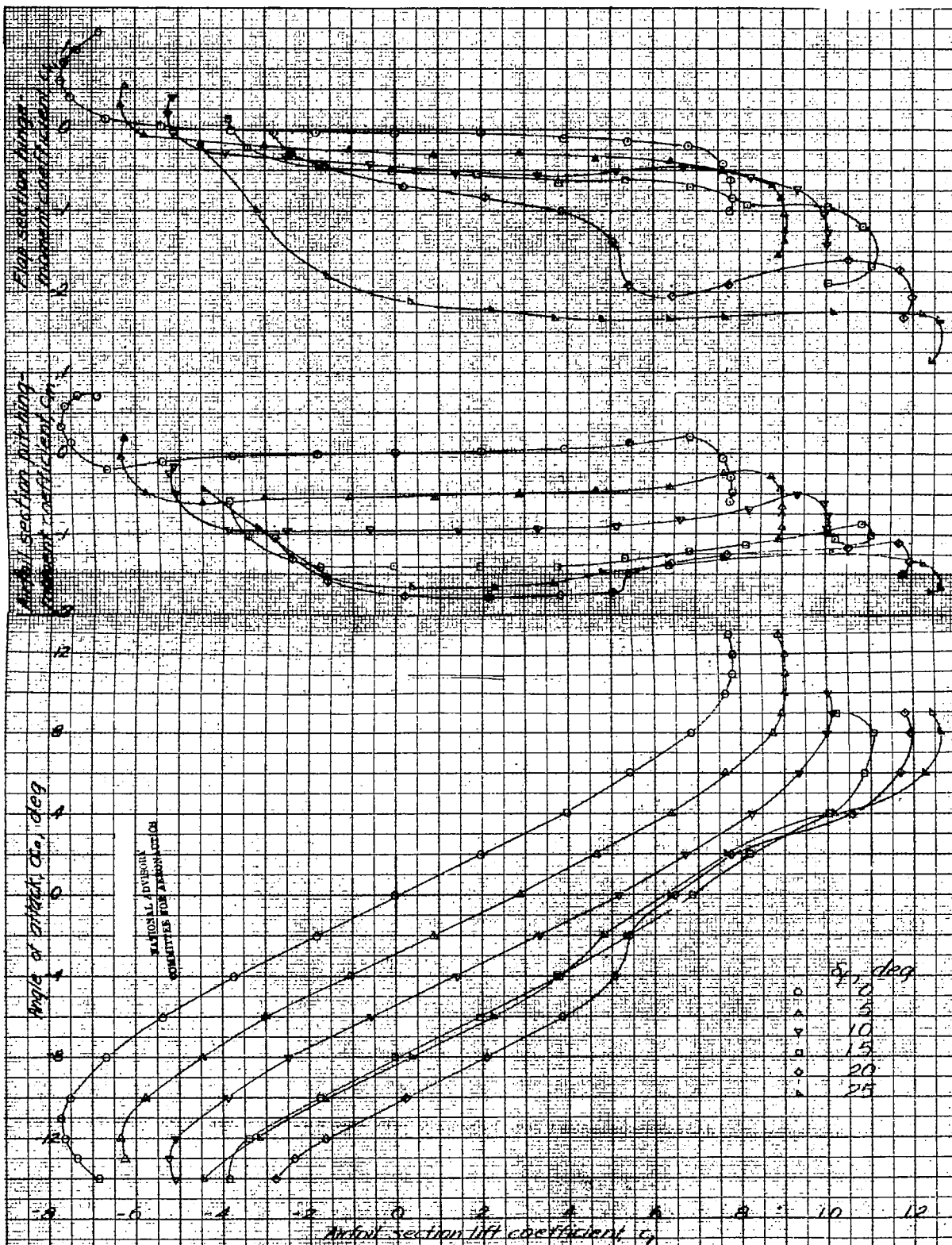


Figure 8. Section characteristics of airfoil for XP-63 horizontal tail. NACA blunt nose flap. Gap sealed.  $q = 100$  lb/ft<sup>2</sup>.

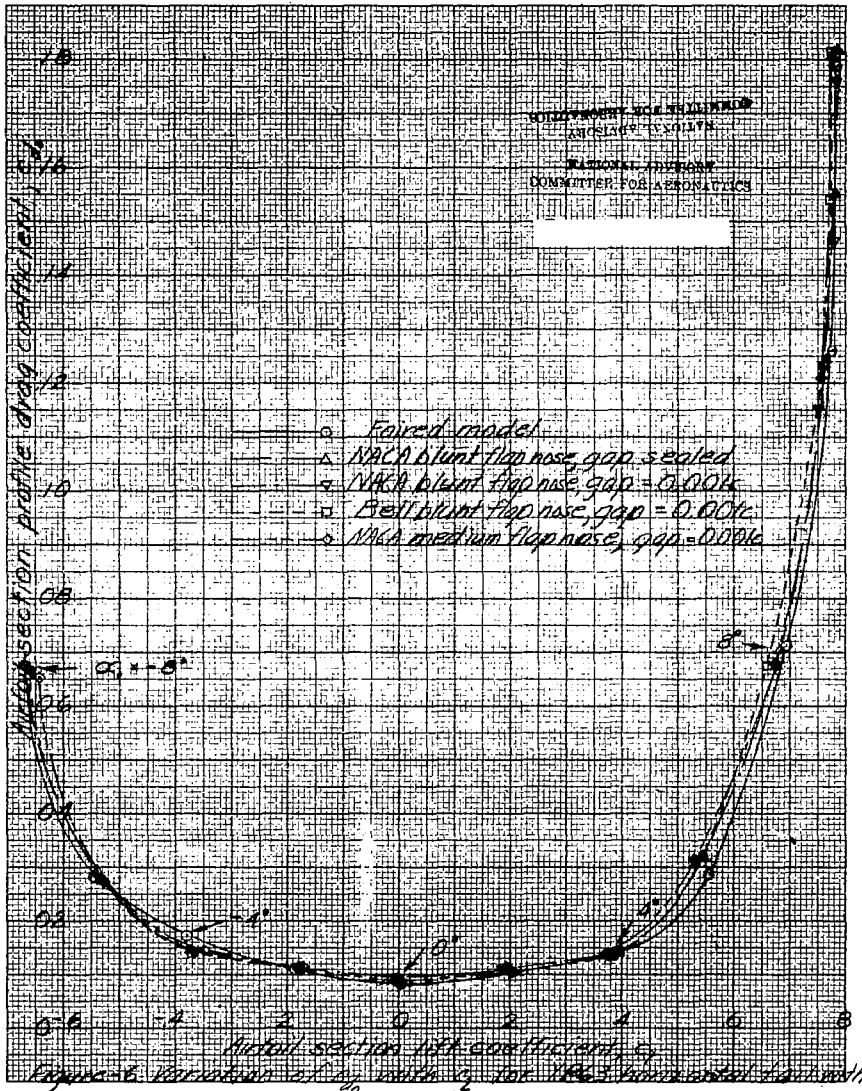


Figure 6. Variation of  $C_D$  with  $C_L$  for NACA blunt flap nose with various flap nose shapes and gaps.  $\alpha = 0^\circ$ ,  $\beta = 0^\circ$ .

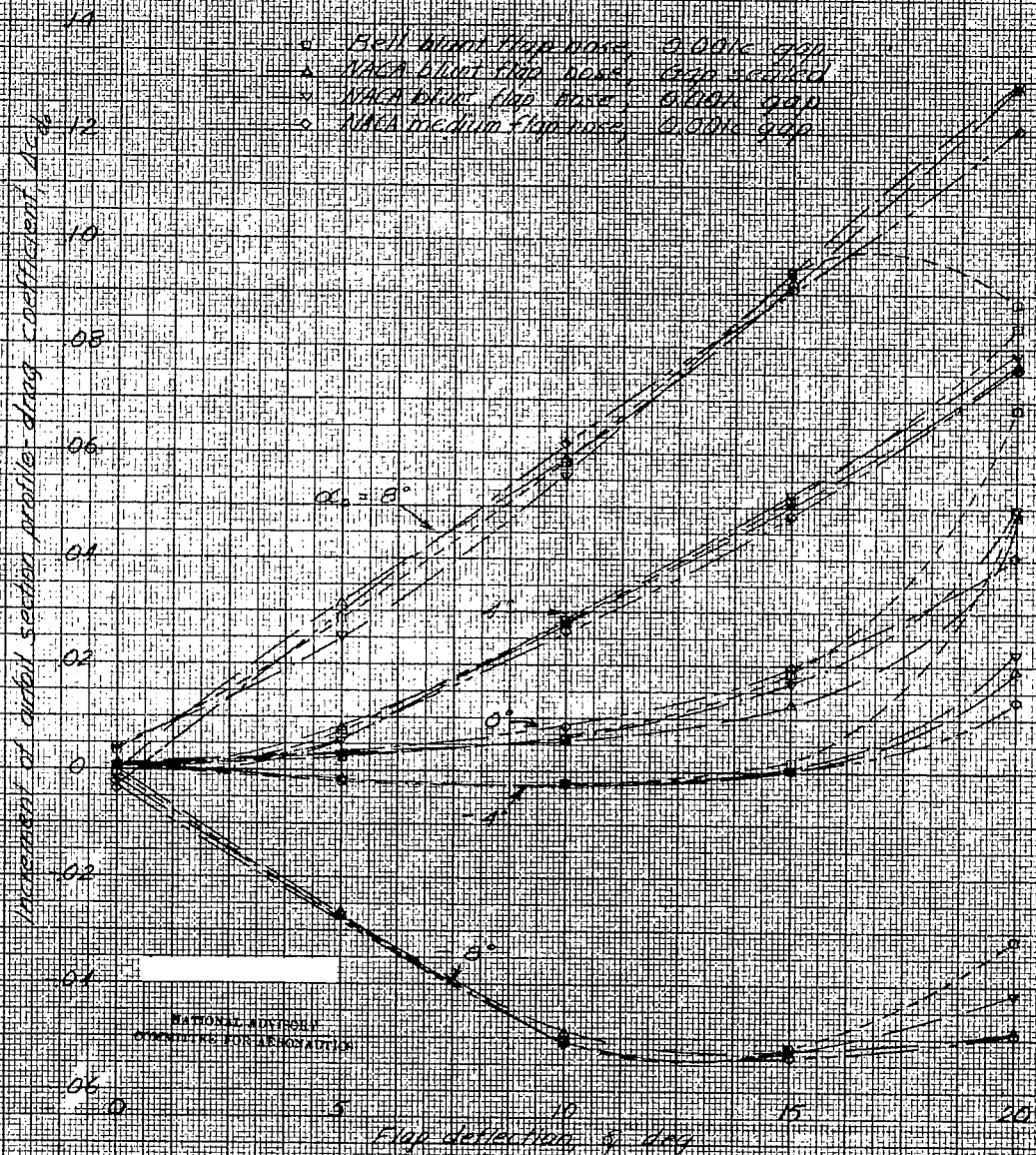


Figure 1. Increments of airfoil section profile-drag coefficient caused by various flap nose shapes. Foiled model with  $\delta = 0^\circ$  and  $\delta = 0^\circ$  used as basic condition (SR-63 horizontal tail)

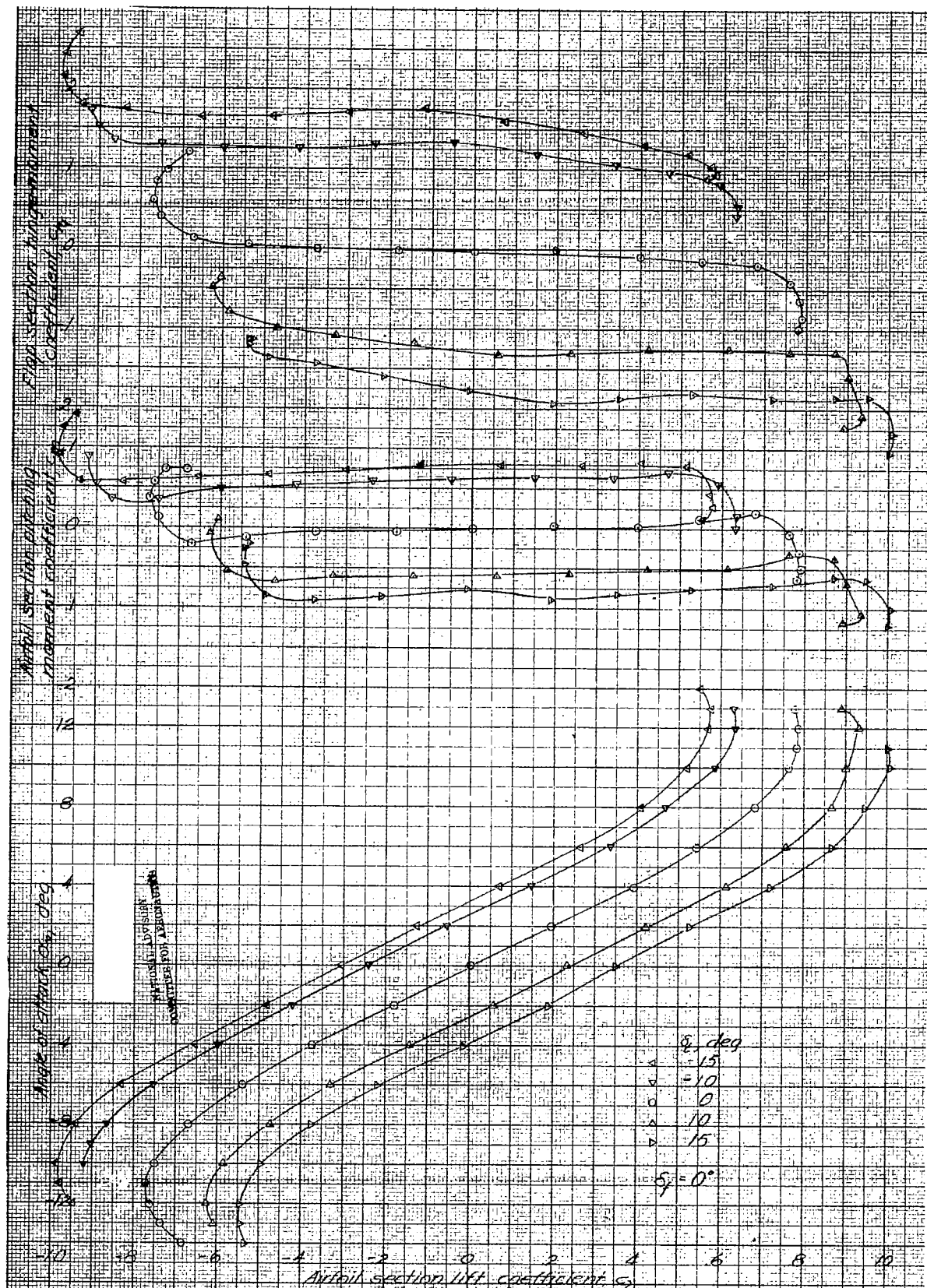
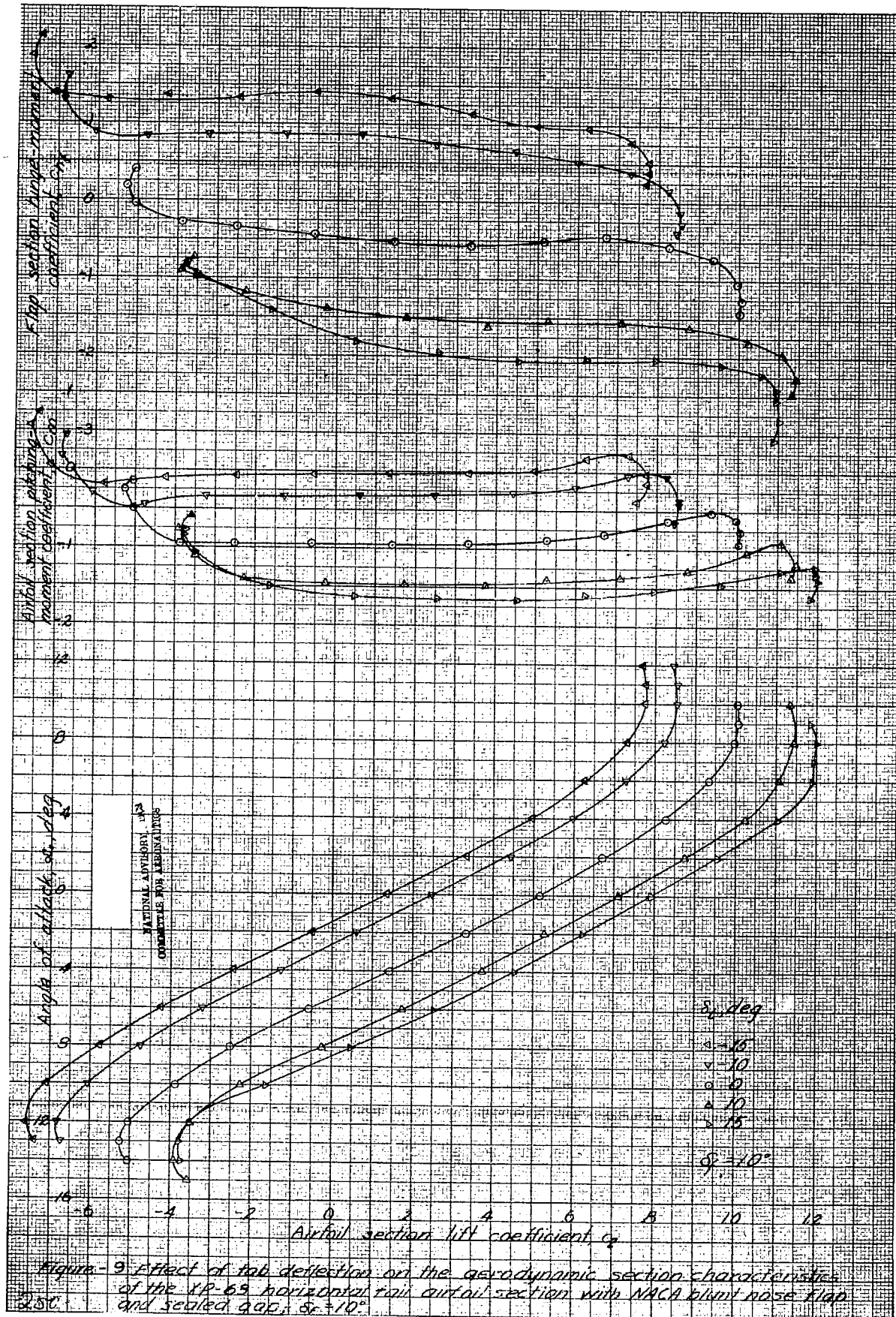


Figure B. Effect of tab deflection on the aerodynamic section characteristics of the XP-63 horizontal tail airfoil section with NACA blunt nose flap and sealed gap,  $\delta_f = 0^\circ$ .



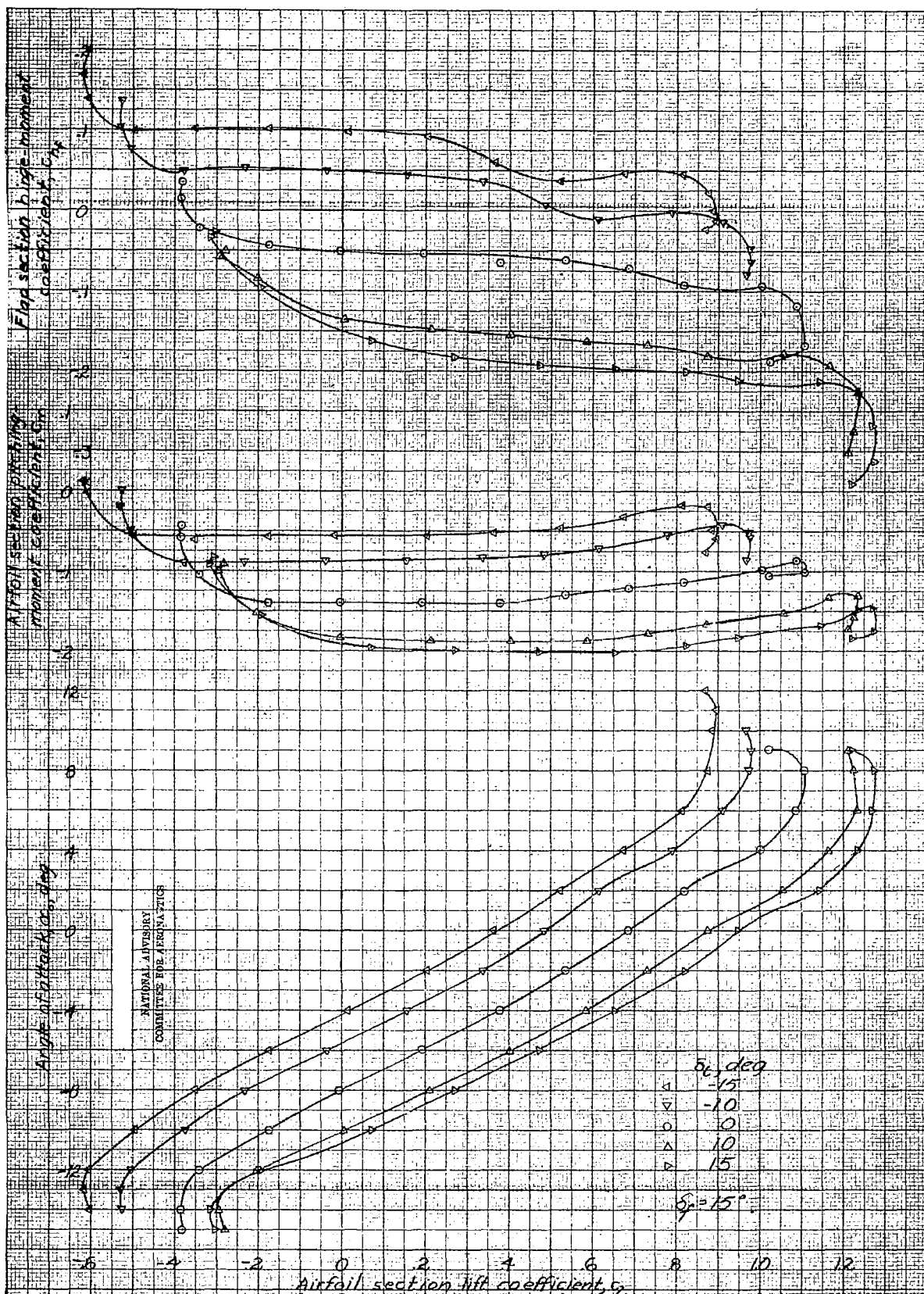


Figure 10. Effect of flap deflection on the aerodynamic section characteristics of the XP-63 horizontal tail airfoil section with NACA blunt nose flap and sealed gap;  $\delta_f = 15^\circ$ .

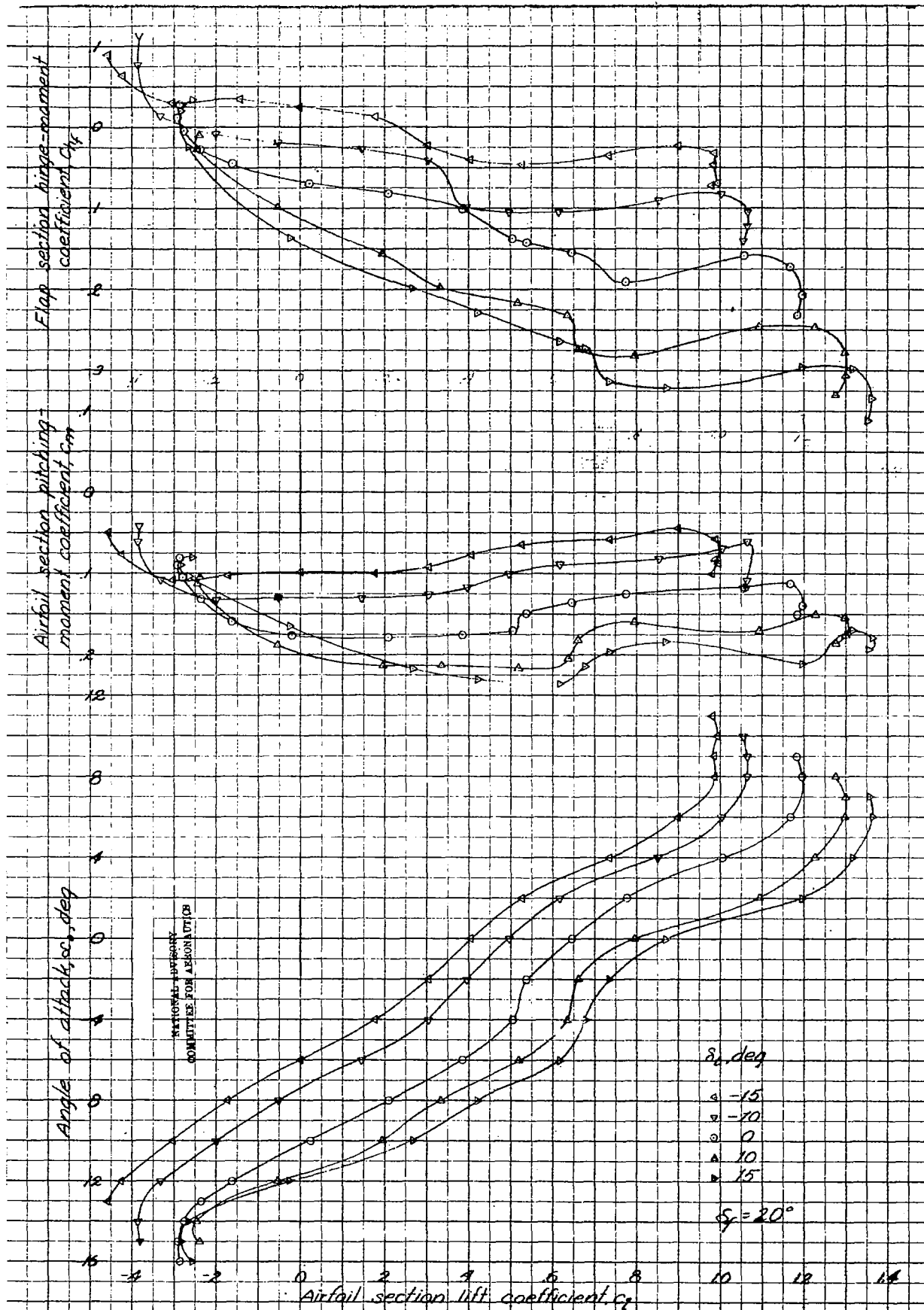
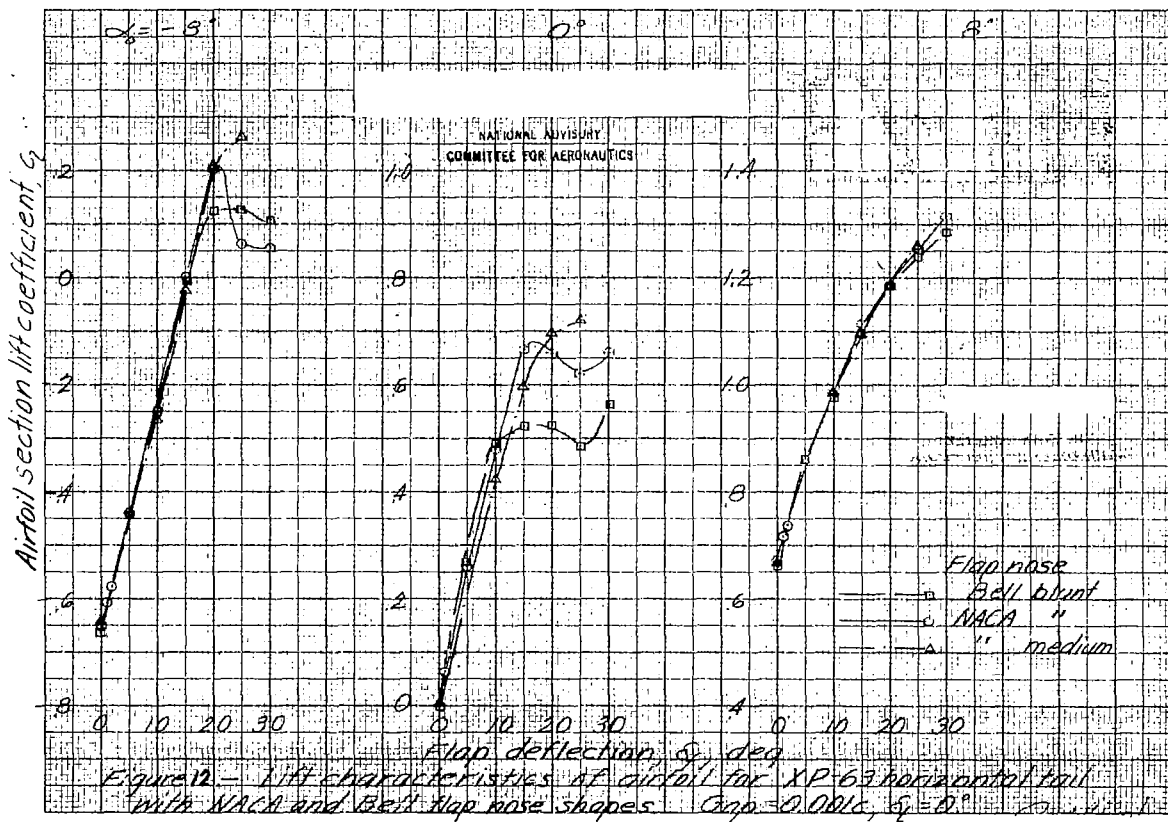
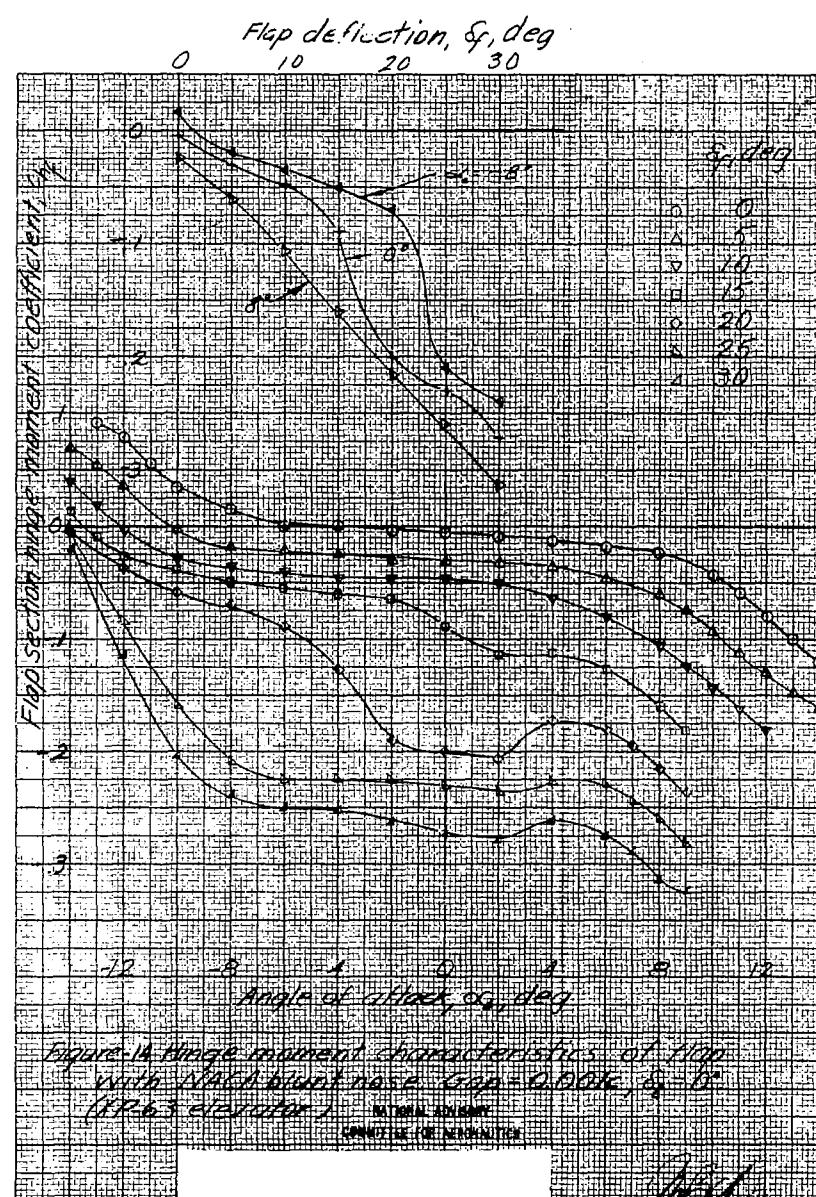
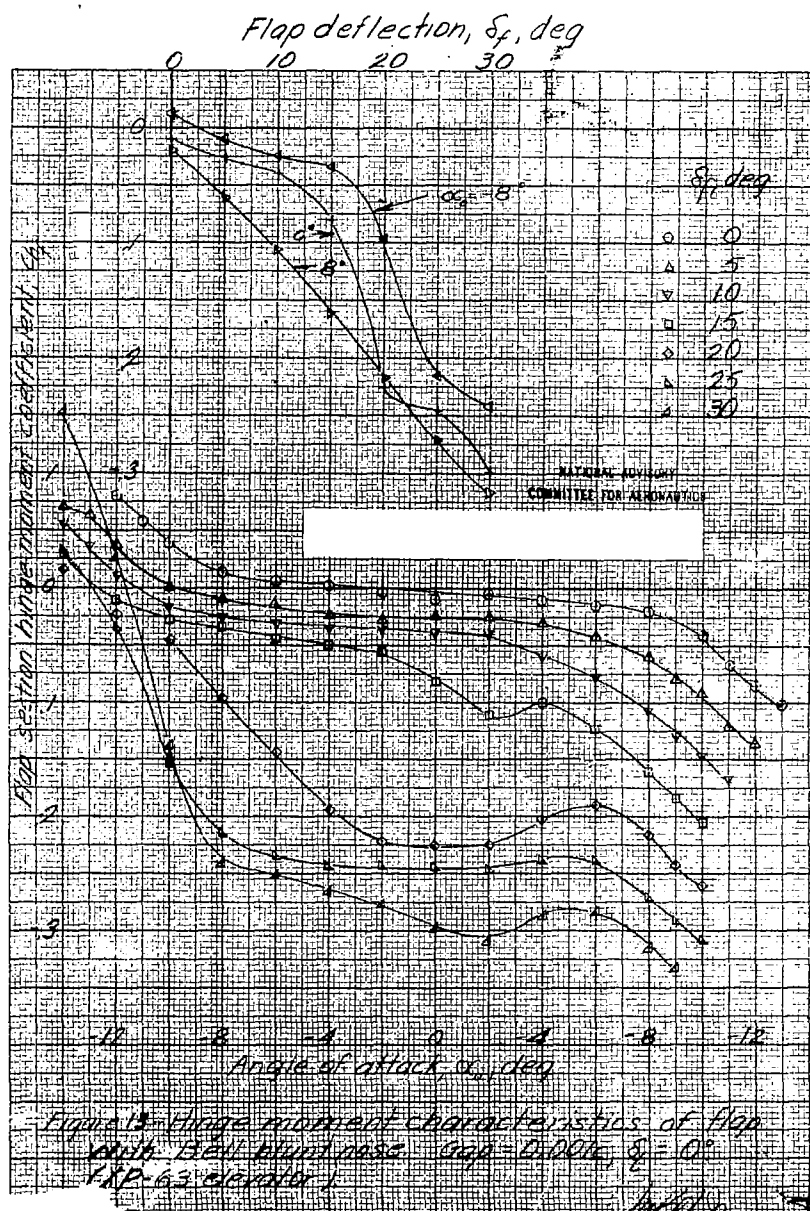
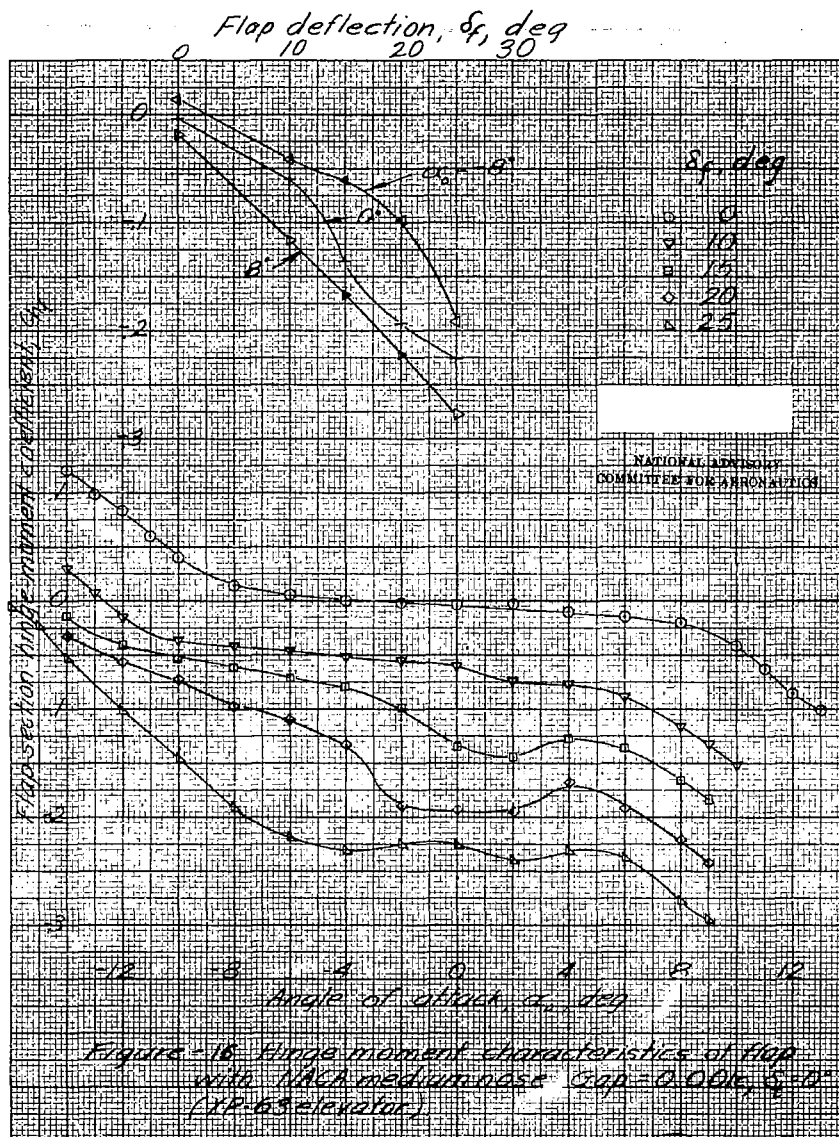
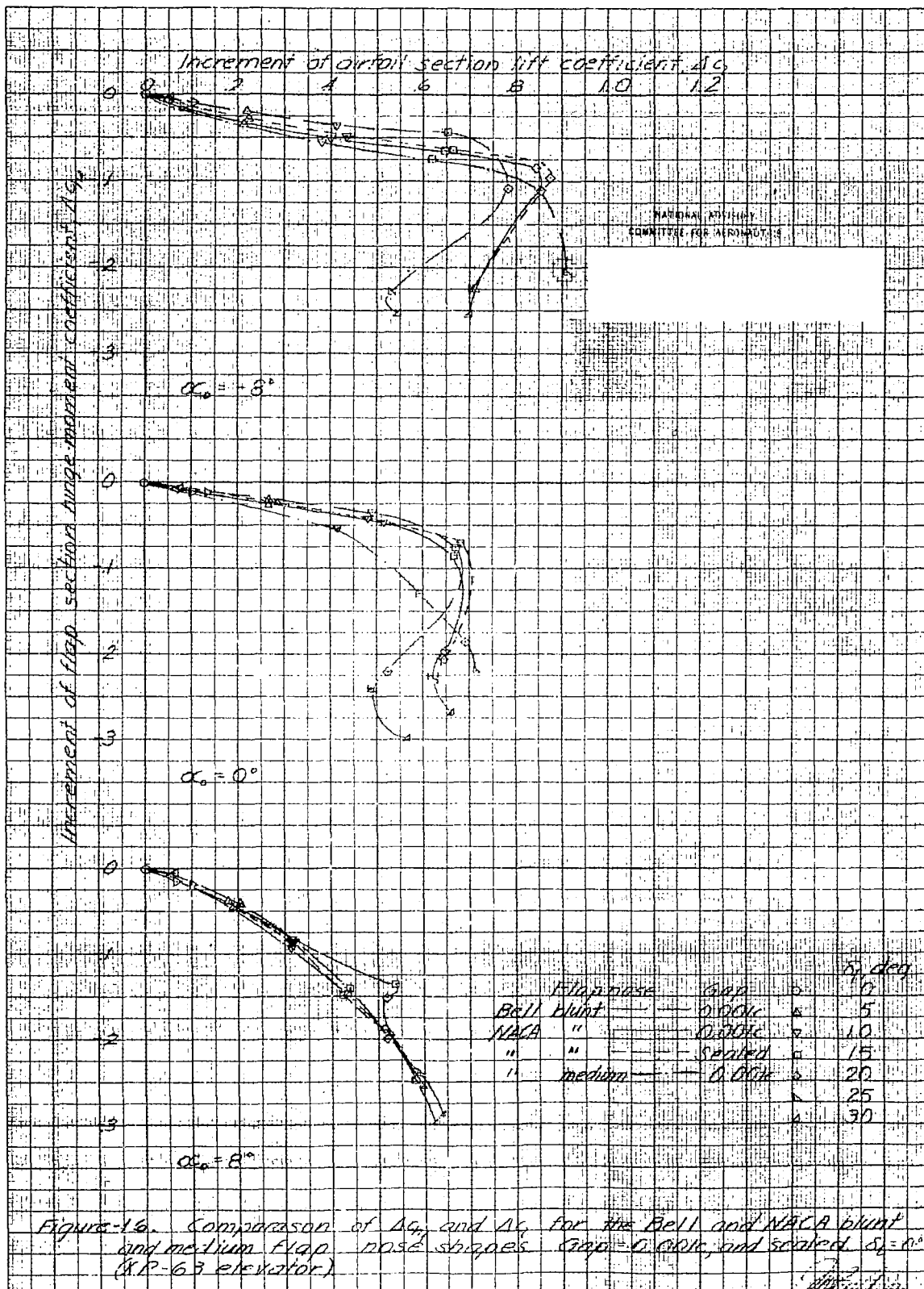


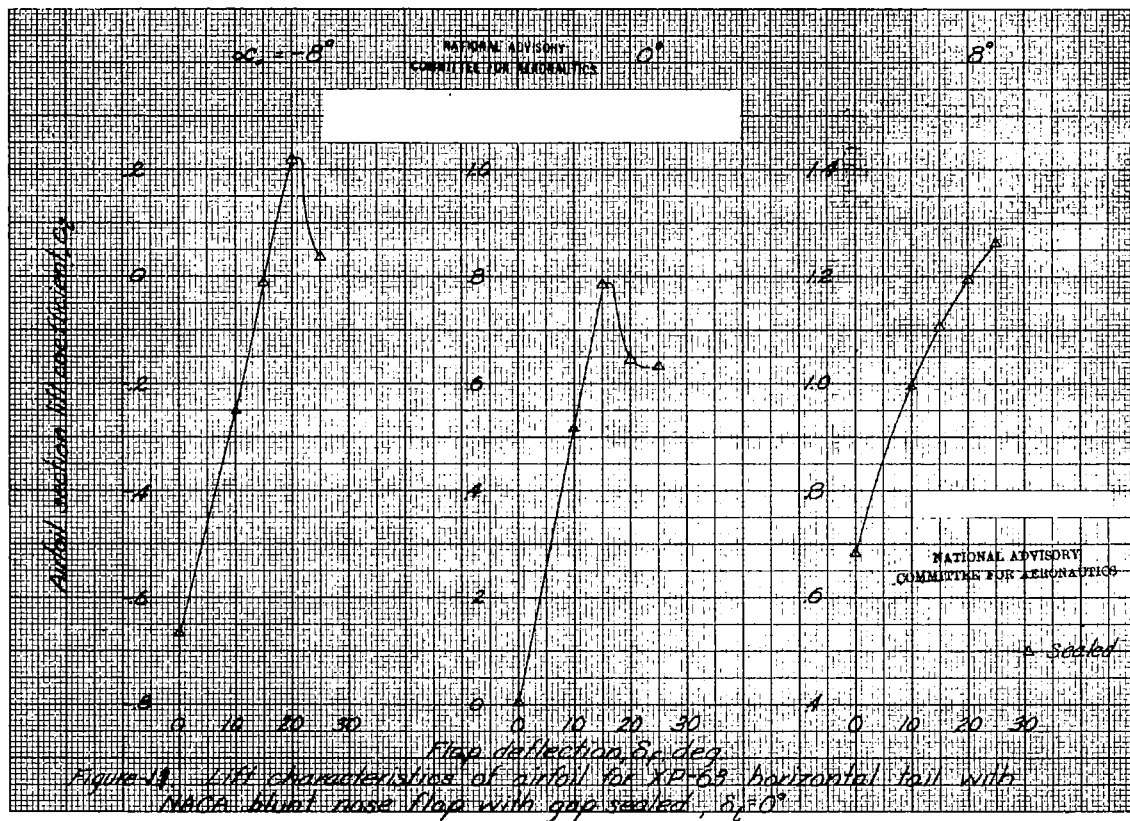
Figure-11. Effect of tail deflection on the aerodynamic section characteristics of the XP-63 horizontal tail airfoil section with NACA blunt nose flap and sealed gap;  $\delta_f = 20^\circ$ .

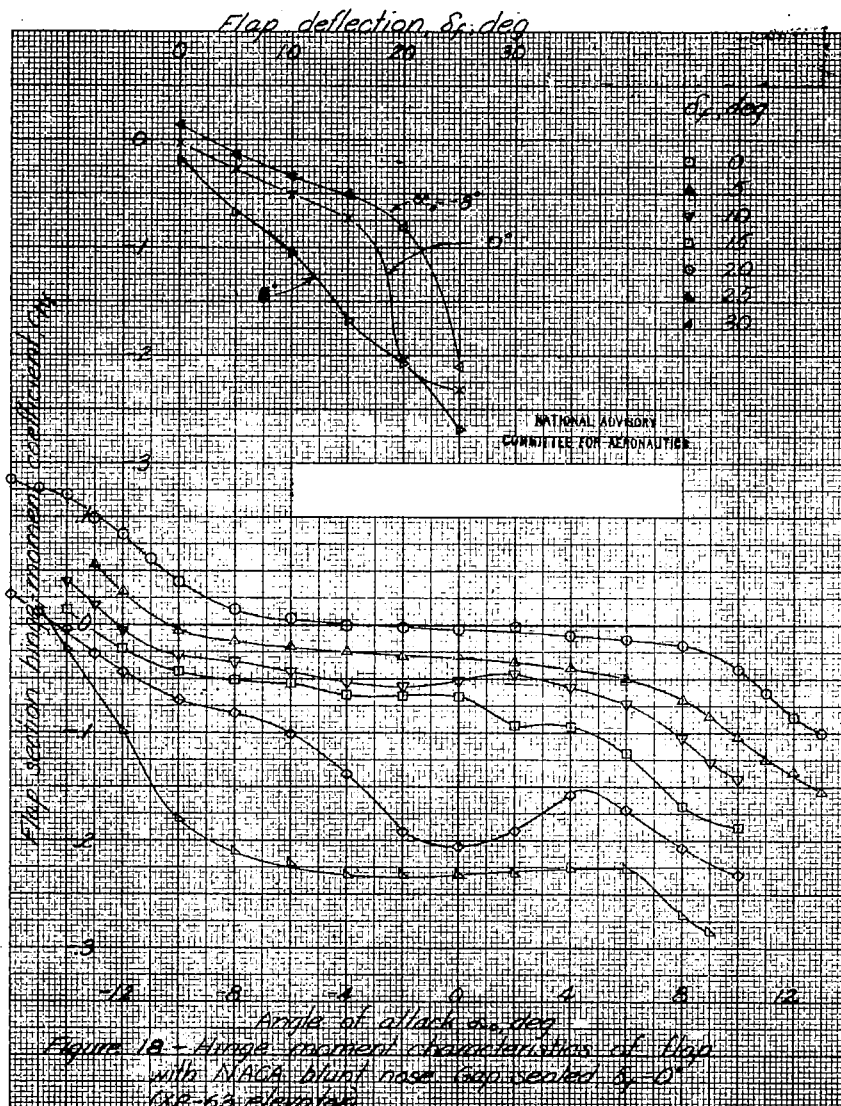












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